

Design and Simulation of Neuro-Fuzzy Controller for Power Factor Correction of Three Phase Diode Rectifier Using Shunt Active Harmonic Filter



Engineering

KEYWORDS : Adaptive Neuro-Fuzzy Inference Systems (ANFIS), Shunt active harmonic filter, Buck regulator, three phase diode rectifier, and DC drive

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ABSTRACT

This work describes a method in improving the input current total harmonic distortion as well as power factor of a three-phase diode rectifier circuit. In this method, three bidirectional switches are used across the three-phase supply and load to eliminate the lower order harmonics and shunt active harmonic filters is connected at input stage to eliminate the higher order harmonics. The buck regulator connected at the output stage regulates the voltage applied to the DC motor load. The Adaptive Neuro-Fuzzy Inference Systems (ANFIS) is used to generate the triggering pulse for the bidirectional switches. The performances of DC motor drive are evaluated with and without shunt active harmonic filter. The analysis and simulation results of three phase rectifier are also presented in this paper.

I. INTRODUCTION

Traditionally, three-phase ac-to-dc high power conversion is performed by diode or phase-controlled rectifiers. Due to the commutation of these structures at the zero crossing of the current, they are also called "line-commutated" rectifiers. These rectifiers are robust and present low cost, but draw non sinusoidal currents or reactive power from the source, which deteriorate the power quality. To compensate for the harmonic distortion generated by the standard diode rectifiers, passive linear filters or power factor correction structures can be employed [1-3]. The multi pulse three-phase rectifiers achieve harmonic cancellation by introducing phase shift by means of special three-phase transformers [4-5]. Moreover, the simplicity and reliability ability of the diode rectifiers are preserved. However, they are heavy, bulky, and expensive.

Three-phase pulse width modulation (PWM) rectifiers are widely employed in low- and medium-power drive applications where the requirements established by international standards should be satisfied [6-9]. These structures are the most promising rectifiers from a power quality viewpoint [10-12] since they can present low harmonic distortion and unity power factor.

Recent trends in high-power rectifiers have introduced a new class of three-phase rectifiers, the hybrid rectifiers [13-15]. The term "hybrid rectifier" denotes the series and/or parallel connection of a line-commutated rectifier and a self-commutated converter. The line-commutated rectifier operates at low frequency and has a higher output power rating. The active rectifier is designed to operate with a small power rating and at a high switching frequency [16].

Three phase diode rectifier with bi directional switches and the buck converter at the output stage is implemented [17]-[21] with DC and AC drive applications. The performance of diode rectifier is verified with only one controller.

In this paper, we propose a simple buck converter at the output stage of three phase diode rectifier with Shunt active harmonic filter. The buck converter regulates the voltage at the output stage for speed control applications. The Adaptive Neuro-Fuzzy Inference Systems (ANFIS) is developed to improving the conduction period of the bi directional switches. The new technique is simulated with DC drive application by PI controller as well as Adaptive Neuro-Fuzzy Inference Systems (ANFIS) and the results are compared.

II. ANALYSIS OF PROPOSED DIODE RECTIFIER WITH BUCK REGULATOR

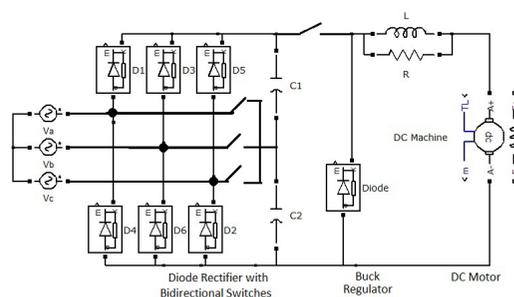


Figure 1: Proposed diode rectifier with buck regulator

The circuit diagram of proposed diode rectifier with buck regulator is shown in Figure 1. Two main situations can be identified:

1. In the first situation, there are only two conducting diodes. As a result, on a conventional three-phase rectifier, the current on the third phase remains null during that interval. In the circuit, the switch associated with the third phase is gated on during that interval. For instance, during the 0 to 30 stage, the bidirectional switch is gated on, so the input current evolves from zero to a maximum value.
2. In the second situation, there are three conducting diodes, one associated with each phase. The three switches are off, so the converter behaves like a conventional rectifier with input inductors.

III. ADAPTIVE NEURO-FUZZY INFERENCE SYSTEMS (ANFIS)

The objective is to design Adaptive Neuro-Fuzzy Inference Systems (ANFIS) that will improve the input current total harmonic distortion (THD) as well as power factor at the input stage by controlling the conduction period of the bidirectional switches. The ANFIS will use both the output current and output current error of the circuit as input and obtain a control signal as its output. The controls signal will then increase or decrease the conduction period of bi-directional switches that will either achieve the desired power factor at the input stage.

The scheme utilizes Sugeno-type Fuzzy Inference System (FIS) controller, with the parameters inside the FIS decided by the neural-network back propagation method. The ANFIS is designed by taking current (I) and error in current (e) as the inputs. The output stabilizing signals is computed using the Fuzzy membership functions depending on these variables. ANFIS-Editor is used for realizing the system and implementation. In a conventional fuzzy approach the membership functions and the

consequent models are fixed by the model designer according to a prior knowledge. If this set is not available but a set of input-output data is observed from the process, the components of a fuzzy system (membership and consequent models) can be represented in a parametric form and the parameters are tuned by neural networks. In that case the fuzzy systems turn into neuro-fuzzy system. A fuzzy system can explain the knowledge it encodes but can't learn or adapt its knowledge from training examples, while a neural network can learn from training examples but can not explain what it has learned.

A. Fuzzy Variables

Output Current, error (e) in current and Output Control Signal (CS) are detection as Negative Large (NL), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Large (PL), Positive Medium (PM) and Positive Small (PS).

B. ANFIS Model Structure

The ANFIS Model Structure is shown in Figure 2.

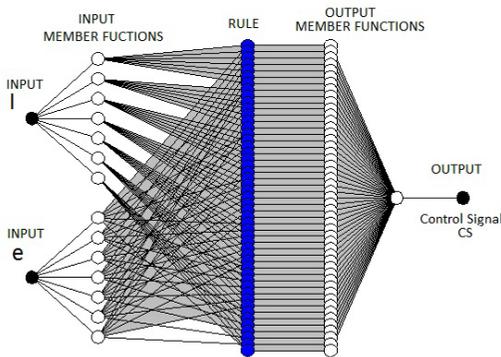


Figure 2: ANFIS Model Structure

IV. SIMULATION RESULTS

The Adaptive Neuro-Fuzzy Inference Systems (ANFIS) based simulation diagram of three phase diode rectifier is shown in Figure 3.

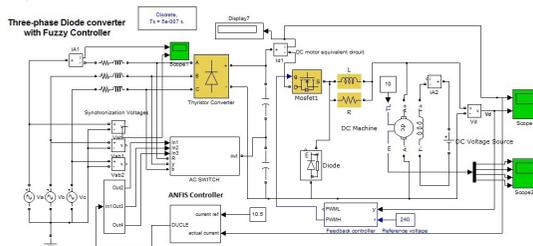


Figure 3: ANFIS controller based simulation diagram of three phase diode rectifier

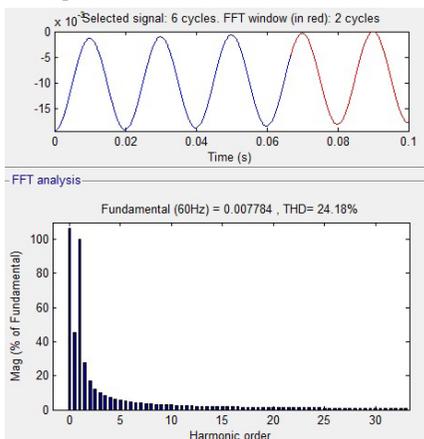


Figure 4: The input current waveform and THD of three phase diode rectifier for ANFIS control

Figure 4 shows the THD value of input current as 24.20%, which is not acceptable and is due to the higher order harmonics. The shunt active filter is connected at the input stage to reduce the higher order harmonics with the THD value of 0.01% as shown in Figure 5.

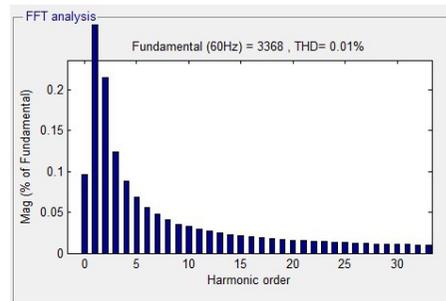


Figure 5: The input current waveform and THD with shunt active filter

The efficiency of the DC motor is evaluated for different torque conditions with and without shunt active filters and tabulated in Table 1. The efficiency of the DC motor is improved while shunt active filter is connected.

TABLE - 1
Efficiency of DC motor

TORQUE N-m	Efficiency	
	Without Filter	With Filter
1	33.38	33.52
2	54.58	54.83
3	61.45	62.02
4	67.55	67.65
5	68.71	68.77
6	70.03	71.18
7	70.83	71.30
8	75.16	75.70
9	79.75	80.07
10	85.78	86.56

The relation between torque and efficiency of DC motor with and without shunt active filter using ANFIS controller is shown in Figure 6.

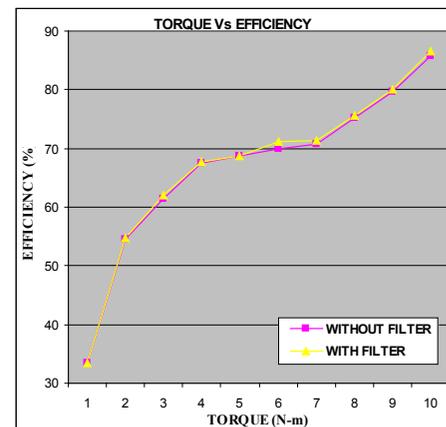


Figure 6: Variation of efficiency of the DC motor

V. CONCLUSION

The simulation results are obtained for three phase rectifier with and without shunt active harmonic filter using Adaptive Neuro-Fuzzy Inference Systems (ANFIS) show that sinusoidal input supply current waveform presents at the input stage. A power factor and input current THD improvement for a DC motor load has been verified.

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